Measuring Individuals Valuation of Health Care: Labour Market Perspective*

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August 8, 2016

1 Introduction

How can we value improvements on quantity and quality of life? This question has motivated several research agendas in economics literature, from labour to health economics, involving both theoretical and applied contributions. This white paper explores this question from the perspective of the economic benefits generated by health improvements. In order to value the contribution of a particular policy or technology we will explore the ability of life-cycle model for deriving counterfactual scenarios. The following sections provide a guide about how to use this tool when considering health evolution, and present some studies related to it with special emphasis on labour economics.

The first part of this white paper is devoted to the building blocks required for estimating the value of health-related interventions using life-cycle models. It starts with a a review of the main concepts in economics evaluation, including *Cost Benefit Analysis* (CBA), *Cost Effectiveness Analysis* (CEA), *Quality Adjusted Life Year* (QALY) and *Willingness to Pay* (WTP). This last concept is explored in detail within the life-cycle model framework. In this setup, two elements of the model's are explored: how to measure and model quality of health and its relation with the utility function, and how to model its evolution.

The second part presents a review of the literature that has considered life-cycle models that include health evolution. Rather than a comprehensive review, I briefly present a selected group of articles that highlight the main elements to consider when modelling health in the life-cycle context. A first group explores models that consider how economic activity is shaped by current and future health shocks. This literature explore their consequences on individual choices such as health expenditures and lifestyle, but also on savings and labour supply. It also covers the role of health and disability insurance, and of social security. The second group presents themes in which I consider there is substantial work to do. First, how to incorporate subjective beliefs information into structural life-cycle models. Second, how this models can be used for improving evaluation of health-related interventions.

2 Measuring the gains of adopting a health technology

There are two main tools in economic evaluation analysis: cost-benefit (CBA) and cost-effectiveness (CEA). The essential difference between the two of them is that the first one is based on a subtraction, while the second on a division. This means that the first one set both costs and benefits in the same scale, whereas the second allow them to be in different units. For instance, under CEA it is possible to report measures in terms of euros invested per years of life gained, rather than the net benefit in millions of euros which will be the result of a CBA. The main rationality behind this difference is to avoid making explicit the conversion between units, in particular from years of life into monetary units

*White paper prepared for the NBER-IFS International Network on the Value of Medical Research
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[McIntosh, 2010]. This difference is not essential for the life-cycle framework, however almost all the literature using this tool is under the CBA. What is central for our discussion is how to measure the gains from a treatment, rather than how to compare them with costs.

The calculation of the additional QALY derived from a given health intervention is the strong suit of the CEA literature for measuring benefits. Indeed, assessing the extra QALYs generated by a particular treatment is standard in institutions as the *National Institute of Clinical Excellence* (NICE) in the UK among other regulators and health-related agencies around the world [Lipscomb et al., 2009]. It is a simple measure that combines quantity and quality of life. In it, for a given health state a *health utility* is assigned, which is a number that represents quality relative to a life without health problems (*utility* of 1) and death (*utility* of 0) [Phillips and Thompson, 2001]. For instance, under the EQ-5D valuations[1] the number 0.329 is assigned to someone who is not anxious or depressed and has no problems for walking, but who finds it difficult to wash or dress himself and cannot perform usual activities and experiences some pain. If such person is confined to bed and experiences depression, extreme pain and cannot wash or dress himself, the number is -0.429.[2] While it is true that such numbers can be considered as arbitrary, they provide a standard for making policy decisions. However, their use for measuring the economic gains of a health technology might be more controversial as they do not tell us anything about how economic choices as labour participation, household savings, or insurance-take-ups are affected by modifying the odds of transiting between health states. These 'side-effects' are central for understanding how innovations affect a society, specially if we consider areas as cardiovascular-diseases or cancer which affect large shares of the population.

A different strategy comes from answering the following question: how much will a person give up in order to enjoy the benefits of a given treatment? Such question motivate the *willingness-to-pay* (WTP) measures, which is derived directly from the concept of *Compensated Variation* in welfare economics. Equation 1 makes it explicit: WTP is the monetary transfer that will ensure an individual i with wealth W_i and characteristics $\Omega_i(0)$[3] gets the same level of utility $\bar{V}$ that would obtain if the treatment was available so those characteristics were $\Omega_i(1)$.[4]

$$\bar{V} = V_i(\Omega_i(1), W_i) = V_i(\Omega_i(0), W_i - WTP_i) \tag{1}$$

An approximation to this object can be obtained when it is clear how the treatment affects Ω_i. For instance, if we know that a particular medication increases odds of survival by a given amount. Hence, the *marginal willingness to pay* (MWTP) can be derived as shown in Equation 2. For it, it is required to understand how the treatment affects utility, and how wealth affects utility. In a standard microeconomic setup, the MWTP can be derived via *revealed preference* approach. That is, by measuring consumer's response to price variations.

$$MWTP = -\frac{dW}{d\Omega_i} = \frac{dV_i/d\Omega_i}{dV_i/dW_i} \tag{2}$$

The main complication comes from considering non-marketed goods and services or when there are market failures, as prices are not available or are distorted. For instance, drug prices are fixed in the UK and there is free access to health care services. As a result, it is possible apply a *stated preferences* approach, or to use an indirect revealed preference method. Stated preferences, also known

[1] This measure of quality of life is based on 5 dimensions: mobility, pain/discomfort, self-care, anxiety/depression and usual activities (work, study, etc.), calculated over 245 states. This is the standard measure used in NICE appraisals and was constructed using a survey valid for the UK.

[2] These are states 12321 and 33332. The reference is state 11111, where no problems are experienced.

[3] This is the information set available for the decision taker. This includes state variables, beliefs and expectations assuming that the treatment is not in place and was not anounced. All of them are taken into account by the individual for making choices.

[4] See Zweifel et al. [2009] and McIntosh [2010] for a simple exposition of these concepts applied to health-related decisions.

as *contingent valuation*, is a method based on surveys that ask directly for the willingness to pay for a treatment considering hypothetical scenarios. On the other hand, indirect revealed preference methods are based on choices that are connected with the object of interest and serve as a proxy for its actual perceived value. For instance, the value of life literature is based on the implicit values present in the trade-off between wages and mortality risk of certain occupations [Viscusi, 1993]. Another example is presented by Clarke [2010], who describes a travel cost model for valuing services such as mammographic screening which have no consultation fee in rural Australia.

Is in the context of the WTP that life-cycle models are essential. These type of models provide a framework for considering how to attach a given value which is consistent with economic theory. It is possible to derive the WTP for QALY, but the assumptions required to make the estimates equivalent are strong. Nordhaus [2003] use estimates from labour literature on the value of life jointly with a simple life-cycle model in order to quantify the output of health care sector for the second half of XX century. His calculations show that "improvements in health have been as valuable as all other sources of economic growth combined." The following section will discuss in detail the main elements of this type of models in current literature.

2.1 Willingness-to-pay in the life-cycle framework

This section will explain how to value health in terms of the life-cycle model with variable lifetime and health. This useful tool, introduced by Modigliani and Brumberg [1954], presents three main advantages for the analysis of a health-related intervention. First, they allow to calculate how much present value of lifetime utility changes due to variations on mortality and morbidity processes. Second, it is possible to infer choices conditional on both health and mortality prospects. In other words, it is possible to construct counterfactual scenarios in which predicted decisions will consistent with forward-looking behaviour. Third, they account for dynamic selection elements such as mortality and medical expenditures determined by past behaviours [Khwaja, 2010].

First, I follow Murphy and Topel [2006] as an introduction for the main concepts related to WTP in the context of life-cycle models. Second, there is a discussion on how quality of life and its relationship with consumption is modeled in literature. Finally, there is a glance to different strategies for modelling health evolution. This discussion abstracts from elements common to most life-cycle models as budget constrains, endogenous and exogenous income, which are not the focus of this white paper. Also, this is a partial equilibrium perspective, the same building blocks can be used in macro models that consider non-health production sectors or overlapping generations.

2.1.1 Basic elements

A basic life-cycles model with mortality provides an structure in which it is possible to aggregate estimates of the value of statistical life derived elsewhere. Murphy and Topel [2003b, 2006], Nordhaus [2003] are clear examples of this approach. Let's consider a simplified version of Murphy and Topel [2003b] model for a representative agent who gets an utility of death normalised to 0. His longevity is given by a survival to age t function, $S(t)$. The agent enjoys consumption and leisure with an instantaneous utility $u(c(t), l(t))$, and is subject to a discount rate ρ and to a time-invariant interest rate r. A crucial assumption is that income from labour is not restricted by age.

$$V(0) = \int_0^\infty e^{-\rho t} u(c(t), l(t)) \cdot S(t) dt \tag{3}$$

Let's consider a change in utility $dV(t)$ due to a change in survival odds $\Delta S(t)$. The WTP for such change is given by $dV(t)$ divided by the marginal utility of consumption $u_c(t)$. For ease of exposition, Murphy and Topel [2003b] also assume that interest and discount rates are related such that $e^{-(r-\rho)t} = \frac{u(c(t),l(t))}{u(c(0),l(0))}$, which comes from competitive capital and insurance markets. Under this conditions, the WTP from the start of life can be written as follows:

$$\frac{dV(0)}{u_c(0)} = \frac{\int_0^\infty e^{-\rho t}u(c(t),l(t)) \cdot \Delta S(t)dt}{u_c(c(0),l(0))}$$
$$\frac{dV(0)}{u_c(0)} = \int_0^\infty e^{-rt}\frac{u(c(t),l(t))}{u_c(c(t),l(t))} \cdot \Delta S(t)dt$$

Finally, Lets assume that the mortality rate is reduced in a proportion λ after age a, $\Delta S(t) = \lambda S(t) \, \forall t > a$. Given this, we can express the WTP in terms of the *value of a statistical life* (VSL), $VSL(a)$. In other words, how much an individual is willing to give up at age a in order to reduce the probability of death in one unit. This is equivalent to the MWTP concept described above. This can be directly related to the empirical literature on the value of life in order to calibrate the parameters behind a defined functional form of $\frac{u(\cdot)}{u_c(\cdot)}$. Murphy and Topel [2003b] use a figure of $500 at ages 20-65 on 1996 prices, for a 1/10.000 increase in the probability of death, based on Viscusi [1993] calculations. Jointly with consumption and wages data, this calibration allows the authors to simulate the counterfactual scenario in which recent reductions on mortality did not take place. Hence calculate the utility difference between the two scenarios. Nordhaus [2003] assumptions on this model are stronger, but the fundamental goal is the same.

$$\frac{dV(a)}{u_c(a)} = \lambda \cdot \int_a^\infty e^{-r(t-a)}\frac{u(c(t),l(t))}{u_c(c(t),l(t))} \cdot \frac{S(t)}{S(a)}dt = \lambda \cdot VSL(a) \quad (4)$$

From Rosen [1988] and Murphy and Topel [2003b] there are some results which will be relevant for the discussion. First, discounting implies that the reference age for calculations is crucial for determining the value of an intervention. As discussed above, this has been found empirically in the labour literature as well[Viscusi and Aldy, 2003]. Second, there is a positive relationship between wealth and the value of health interventions, which comes from the normalization of death to 0. A clear intuition for this is that while consumption suffers from marginal diminish returns, this is not the case for adding utility via extending life [Hall and Jones, 2007]. Third, intertemporal substitution possibilities and whether income increases with longevity is essential. The basic idea is that there is a tension between the consumption per year and the extend of life: if there are fixed resources, both sources of utility are substitutes. Fourth, contrary to the value of life depends on the level of the utility due to normalization of death to utility level zero.

These models do not include some elements that are essential for life-cycle model analysis: uncertainty on income and bequest motive. Both elements are central for the discussion of the value of medical treatments. Both uncertainty and bequest motive induce savings, and forecasting the odds of disability is relevant for choosing labour and savings. French [2005] introduce both elements into his discrete-time finite-horizon model. As in the model discussed above, individuals choose consumption and leisure, and face mortality risk. However, there are three crucial differences. First, labour income is persistent but uncertain, and non-labour income depends on the social security design. Such elements induce individuals to save due to risk aversion, and reinforce the role of time in the model. Second, health status H_t, a discrete variable, affects utility by reducing the total number of hours available for working or leisure: an individual in bad health can choose from 0 to $L - \phi$ instead of L hours as shown in Equation 5. In this equation, γ represents relative risk aversion and ω the relative importance of consumption relative to leisure in utility. Moreover, income and assets are affected as well by bad health. Thus, the cost of working are different for individuals who are sick. Third, the value of mortality is not normalized to 0 but to a function of assets at death: the bequest motive $b(A_t)$. This element, where individuals get a direct utility for leaving assets after their death, is relevant for explaining savings of the elderly [De Nardi, 2004]. While French [2005] does not estimate the value of health, the model can be used for such purpose. More details on health-contingent utility functions are presented in Section 2.1.2 below.

$$V_a = u(c_a, l_a, H_a) + E_a \left[\sum_{t=a+1}^{T+1} \beta^t S(t-1, a) \cdot (s_t u(c_t, l_t, H_t) + (1 - s_t) \cdot b(A_t)) \right] \tag{5}$$

$$u(c_a, l_a, H_a) = \frac{\left(c_t^{\omega} \cdot (L - l_t - \phi I\{H_t = \text{bad}\})^{1-\omega} \right)^{1-\gamma}}{1-\gamma} \tag{6}$$

In complex models such as French [2005], MWTP is not straightforward. The expression from Equation 5 relies on several strong assumptions on labour supply which are not adequate when considering labour supply considerations. In such scenarios, a numerical solution is required. In literature with this type of models, WTP is calculated directly from Equation 1. This requires to solve the problem expressed in Equation 7, which normally implies a numerical solution as in Papageorge [2014] and Rodriguez-Lesmes [2016]. In some applications, Government budget is neutralised by adjusting tax rates as in Low and Pistaferri [2010].

$$WTP_i = \underset{\pi_i}{\text{argmin}} \left| V_i(\Omega_i(1), W_i) - V_i(\Omega_i(0), W_i - WTP) \right| \tag{7}$$

2.1.2 Quality of health and the life-cycle model

How to incorporate quality of health into utility functions in a relevant discussion. In the Murphy and Topel's [2003b] utility discussed above, Equation 3 is extended by adding health status $H(t)$. Equation 8 shows the derived willingness to pay for a change of $\Delta H(t)$. This multiplicative assumption implies that the marginal utility of consumption and leisure is affected by health.

$$\begin{aligned} V(0) &= \int_0^{\infty} e^{-\rho t} H(t) \cdot u(c(t), l(t)) \cdot S(t) dt \\ \frac{dV(0)}{u_c(0)} &= \int_0^{\infty} e^{-rt} \frac{u(c(t), l(t))}{u_c(c(t), l(t))} \cdot S(t) \frac{\Delta H(t)}{H(t)} dt \end{aligned} \tag{8}$$

In the context of an discrete time infinite horizon life-cycle model,Palumbo [1999]considers a multiplicative version for estimating a model on health expenditures, but found no improvement on the fit of the model predictions with *Panel Study of Income Dynamics* (PSID). De Nardi et al. [2010] follow the same preferences in a similar context and also cannot reject that this parameter is different from 0.

$$u(c_t, H_t) = f(H_t) \cdot \frac{c_t^{1-\gamma}}{1-\gamma}$$

Hall and Jones [2007] go to the other extreme and assume an utility function that is additive separable on consumption, c_t, and health status, H_t. As in Palumbo [1999] and De Nardi et al. [2010], this assumption implies that marginal utility of consumption is independent of health. Hall and Jones [2007] point out that it is not clear how (sign) marginal utility of consumption would be affected by deteriorating health. The proposed utility presented in Equation 9[5], takes into account consumption and quality of life *à la* QALY. , Moreover, as in the basic model described before, death is normalized to $u(c_t, H_t) = 0$. As a result, after calibrating risk aversion parameter γ and the discount rate from literature, three equations are used in order to identify the remaining parameters: relevance of health relative to consumption, α, and risk aversion for health σ. The first one is the value of life from literature equated to the theoretical counterpart, just as in the previous section. The other two are

[5] In their paper, the authors allow for variation both in age and period (calendar year).

based on the QALY notion. The idea is that QALY weights represent the relative flow of utility that will be obtained relative to a person in full-health. As a result, using estimates from literature at three different ages, a simple cross-multiplication can be applied in order to relate the age-specific period utilities, as shown in the two Equations in 10.

$$u(c_t, H_t) = b + \frac{c_t^{1-\gamma}}{1-\gamma} + \alpha \frac{H_t^{1-\sigma}}{1-\sigma} \tag{9}$$

$$\frac{u(c_{20}, H_{20})}{0.94} = \frac{u(c_{65}, H_{65})}{0.73} = \frac{u(c_{85}, H_{85})}{0.62} \tag{10}$$

Less restrictive utility functions have been used in literature. For example, an utility that is Cobb-Douglas on non-health goods, but allows for a constant elasticity of substitution (CES) different from 1 between those goods and quality of health. Halliday et al. [2015] presents such utility function in the context of a model that considers labour supply and consumption.This is a similar context to Equation 5 discussed above, so notation in Equation 11 follows the same notation. As in Hall and Jones [2007], there is a constant b for avoiding negative utility values, calibrated according to the VSL literature; and a weight for health relative to other goods consumption $\tilde{\alpha}$. The advantage of the CES between consumption-leisure and health is that it allows to explore whether they are complements or substitutes. In their calibration exercise based on aggregate data, the authors found evidence of complementarity. This type of specification has been used by Yogo [2016], who instead of labour supply considers housing and calibrated the model with parameters that implied substitutability between non-health and health goods.

$$U(c_t, D_t, H_t) = b + \frac{\left[(1-\tilde{\alpha}) \cdot \left(c_t^{\omega} \cdot (L - l_t)^{1-\omega}\right)^{\psi} + \tilde{\alpha} \cdot H^{\psi}\right]^{\frac{1-\gamma}{\psi}}}{1-\gamma} \tag{11}$$

Finally, another alternative is to allow health to affect some specific elements of the utility function. As presented before, French's [2005] utility is health-contingent by affecting the endowment of hours available for labour. That parameter ϕ in Equation 5 is identified by the fact that sick individuals work less than healthy individuals, conditional on their current and past lives. Such type of utility function has implications on the marginal utility of consumption and leisure, which are observed via savings and consumption decisions.

2.1.3 Health evolution

Evolution of health is an essential component of any model. The simplest strategy is to consider mortality alone, which is easy to capture empirically via life tables. That is, in order to calculate the WTP in Equation 4, variation on mortality rates is the only requirement. For this, an empirical value of $\Delta S(t)$ can be obtained by comparing the cross-sectional mortality per age and gender observed in a given year. While this procedure is probably overestimating mortality of younger generations, it is simple to do. However, availability of health measure in several longitudinal surveys allow for better dynamic health production functions.

The most common health-related information in microdata is *self-reported health status* (SRH). Typically, individuals face a Likert scale question where they have to report how is their general health. Options range from *Excellent* to *Very Bad*, depending on the survey. This discrete measure of health, despite of its limitations,[6] introduce variation on the data that has been exploited in several

[6] For instance, within the same survey, individuals might report different health status if asked twice [Crossley and Kennedy, 2002]. Also, it is very difficult to compare among groups, for example, between countries [Jürges, 2007] or even social-groups [Zajacova and Dowd, 2011]. For labour economics, individuals might report bad health in order to justification their early retirement decisions [Bound, 1989]. van Ooijen et al. (2015) proposes a correction of such measurement error issues if there is administrative data available.

models. In a discrete-time model, health status is normally assumed to follow a Markov process; in other words, that is enough to know current health status H_t in order to derive the probability of next period health status being at k level : $p_{kl} = Pr(H_{t+1} = k|H_t = l)$. The most straightforward alternative is to estimate such transition probabilities is to obtain a fully non-parametric estimate. That is, to identify the transition probability p_{kl} based on the observed proportion of individuals who are in state k given that they were previously observed at l health state: $\hat{p_{kl}} = E_i[H_{t+1} = k|H_t = l]$. This can be done conditional on gender, regions, age groups, etc., and is similar to the strategy used in Markov decision models for health economics evaluation. However, there are two limitations for this strategy. First, in health evolution is a function of several independent variables such as lifestyle decisions, health treatments and so on, sample size reduces notoriously for calculating the averages. Second, in the context of endogenous health evolution, this procedure does not account for dynamic selection. For instance, individuals who believe that their health is going to be very bad in the future decide to engage in unhealthy behaviour nowadays. The reason for this is that they expect low returns for adopting their current lifestyle [Adda and Lechene, 2001].

A common procedure for estimating transition probabilities p_{kl}, is to follow a multinomial logit model.[7] For instance, Arcidiacono et al. [2007] estimate their model using data from the *Health and Retirement Study* (HRS), a panel of individuals aged 50 and over in the US. The data includes a SRH question that ranges from *excellent* (1) to *poor* (5), but the authors collapse it into *good* (4-6) and *bad* (1-3) health. This simplification obeys to measurement error problems with SRH, but also because it allows for a reduced state space. Hence, in their model individuals can transit between three health states: good, bad, and death; the last one is an absorbent state[8] as expected. Transition probabilities between them are governed by Equation 12, where X_t is a vector of variables including a constant, health status at t, age, and smoking and drinking at time t. As a result, it is only required to estimate parameters θ^b, θ^d; in total 10 parameters.[9]

$$Pr(H_{t+1} = death|X_t) = \frac{exp(X_t\theta^d)}{1 + exp(X_t\theta^d) + exp(X_t\theta^b)} \quad Pr(H_{t+1} = bad) = \frac{exp(X_t\theta^b)}{1 + exp(X_t\theta^d) + exp(X_t\theta^b)} \tag{12}$$

Finally, the introduction of joint projects between economist and epidemiologist resulted in even richer datasets that include objective continuous measures of health evolution. This includes simple but widely available antrophometrics like weight and height, that can be summarized with the Body Mass Index (BMI) for adults or the World Health Organization z-scores for children. But it also refers to measures like grip strength, blood pressure, cholesterol and sugar concentration in the blood, etc.[10] Continuous health information can be aggregated using factor models, as it is the case of Attanasio et al. [2015a], Cunha et al. [2010], Cunha and Heckman [2008] from the human capital production literature. Such models assume that several continuous variables are noisy measures of a set of unobserved factors. The goal of the measurement system is to extract such unobserved factors, which removes the measurement error. On top of a categorical health status,Darden [2012], using data from the *Framingham Heart Study*, construct a factor that integrates blood pressure and cholesterol

[7]In Arcidiacono et al. [2007] and Khwaja [2010], the authors also considered an ordered logit, a restricted version of the multinomial logit, but both studies report it to be "too restrictive."

[8]In a Markov model and absorbent state is characterized by the impossibility to get out of it. For an absorbent state l, the transition probabilities $p_{ll} = 1, p_{kl} = 0, \forall k \neq l$.

[9]Their model also allows for unobserved heterogeneity, which adds three additional parameters.

[10]Typically, cross-sectional data is available for many countries. For instance the *National Health and Nutrition Examination Survey* (NHNES) in the US or the *Health Survey for England* (HSE) in England. In developing countries, a main advantage is that health surveys typically follow in the form of the *Demographic and Health Surveys* (DHS) program. Longitudinal studies are less common, but such type of information can be found in the main retirement studies in the world. The *Health and Retirement Study* (HRS), the *English Longitudinal Study of Ageing* (ELSA), and the *Survey of Health Ageing and Retirment in Europe* (SHARE). See Guyer and Mary Beth Ofstedal [2010] for a comparison between them. Also, the *National Income Dynamics Study* (NiDS) for South Africa has a restricted set of variables but it covers individuals from all ages. A short panel for all ages but with rich information in the UK if *Understanding Society*, based on the former *British Household Panel Survey* (BHPS).

measures into a unique factor h_{it}.[11] As shown in the simplified Equation 13, the long-run mean of this persistent factor depends on the vector of variables X_{it}, and evolves based on innovations v_{it}. With this auto-regressive specification, it is possible to accommodate both continuous data with the computationally useful Markov property. Moreover, it resembles the original concept of health capital proposed by Grossman [1972] by allowing investment and depreciation of a stock.

$$h_{it} = \rho h_{i,t-1} + X_{it}\eta + v_{it} \tag{13}$$

A final consideration is the distinction between current health and future health. By including a latent risk factor for cardiovascular diseases, authors like Darden [2012] and Rodriguez-Lesmes [2016] are separating individuals information set between elements that affect current utility, and elements that affect the expected value of future utility. This is explicitly analysed by Ozkan [2014], who use information of the *Medical Expenditure Panel Survey* (MEPS) for separating investments on preventive and curative health. Essentially, individuals can mitigate the effects of an innovation on health capital but also can modify the distribution of future shocks.

3 Health and Economic Choices

Rosen [1988] suggested that in order to advance on the valuation of health, it was required to introduce more illness states. This was precisely what occurred in the last decades thanks to computational improvements and availability of rich longitudinal datasets. The following review mentions some of the main breakthroughs in the literature related to life-cycle models and health evolution. Those are elements that are likely to be consider in any analysis that plans to incorporate willingness to pay. Also, I present a couple of topics in which I consider there is work to be done: subjective expectations and how to calculate the value of adoption of medical innovations.

3.1 Health and labour supply: direct and indirect effects

Health shocks have direct effects on labour supply and asset accumulation: the onset of disability. Low and Pistaferri [2010] provide a framework for assessing the value of disability benefits in the US using data from the *Panel Study of Income Dynamics* (PSID). In this model individuals are subject to uncertainty on their income but also on exogenous health shocks that can induce moderate or severe disabilities. In order to smooth consumption, individuals can save but cannot borrow. In this context, every period individuals choose to accept job offers or not; they can also lose their job randomly. Additionally, if unemployed, they can also choose to apply for disability insurance or not. However, such application can be rejected. Retirement is mandatory and mortality certain, therefore disability status is the sole element that connects health with utility: it has a direct multiplicative effect on utility (quality of life effect), but also reduce wages (productivity effect). Their estimates suggest that severe disabilities reduce wages by a 40%.

Not all health shocks end-up in disabilities, however, not participating in the labour market for some periods might have an impact on the evolution of income profiles. Imai and Keane [2004] discuss in depth how learning-by-doing provides an improvement on the fit of models that explain labour supply and wages in the life-cycle. Van der Klaauw and Wolpin [2008] includes not only experience but also tenure for instance.

On top of direct effects, health shocks affect utility via expectations. French and Jones [2011] state very clearly the main aspects of considering health expenditures and health insurance. Risk averse

[11] Alternative aggregation procedures for the biomarkers can be used, as it is the case of Rodriguez-Lesmes [2016] who aggregates similar information using Anderson [2008] procedure. Instead of assuming that there is a noisy common component between all the measures, this technique assumes that each measure might come from an independent factor. Therefore, it maximizes the variance of the resulting index.

individuals have two mechanisms for smoothing consumption in the presence of health shocks: self-insurance via savings, and health-insurance products. However, as the later depends on the specific institutional settings, understanding the effect of health on labour supply typically requires to consider such particularities. The US is the more interesting case as on top of the presence of the biggest health insurance market, *Medicare* offers free health insurance to almost every person over the age of 65. This age is crucial for other benefits of the social security system, making it difficult to answer questions about specific components.

Rust and Phelan [1997] opened the door for the structural analysis of this problem that considers uncertainty. In particular, individuals want to insure against catastrophic events. Their analysis is for a sample of credit constrain individuals from the *Retirement History Survey* (RHS), which covered up to 1979, therefore savings are not considered. In this model individuals can choose whether to work or not, and whether to apply for retirement benefits or not. In this setup the authors conclude that the 65 years old threshold in benefits and health insurance is essential to understand peak retirement at such age for "health insurance constrained" individuals. Apart from better data, the *Health and Retirement Survey* (HRS), Blau and Gilleskie [2001] allow health insurance to vary by job, and allow for random-effects for dealing with unobserved heterogeneity. Still, lack of savings is the main limitation of the model.

French [2005] introduced a structural life-cycle model that combines the social security system with uncertainty on endogenous labour income, and exogenous mortality and quality of health. In the model, individual can self-insure via capital markets but are restricted to borrow against future labour income social security or pensions. A detail modeling of social security is desirable as it enables the author to simulate adequately counterfactuals related to retirement age or amount of benefits. The model is estimated using data from PSID. One striking result is that declining health evolution explains only 7% of the drop of labour participation between ages 56 to 70 in the US. The model is expanded in order to include health insurance decisions in French and Jones [2011]. Among the many other elements of interest in this discussion, it is important to highlight the role of heterogeneity on time-preferences [Gustman and Steinmeier, 2005], joint labour supply of married couples [Blau and Gilleskie, 2008], and the introduction of subjective expectations [Van der Klaauw and Wolpin, 2008]. One missing item is the role of health expenditures as health investments, which is not present in this literature. This will be discussed in the next section.

3.2 Endogenous health investments

Allowing individuals to choose the quality and quantity of their health is one of the most important elements to consider in the life-cycle context. There are two main types of investments: medical expenditures and lifestyle. The former introduce a trade-off with consumption which is similar to asset-pricing models. The later is less standard as the utility function typically requires an adjustment in order to explain the strong persistence of certain behaviours as smoking.

The seminal work by Grossman [1972] introduced endogenous health investments into a life-cycle model. Essentially, individuals are able to produce health by investing monetary resources. Such type of models have been considered for the analysis of the value of life. Hall and Jones [2007]introduced such model. The authors consider an utility that includes both quality and quantity of health (see Equation 9), a health production function, and an utilitarian social welfare function for the society. Health status, the inverse of non-accidental mortality rate, is produced by exogenous improvements in the environment and by health spending which has an increasing productivity over time. Their main result is that health spending has an income elasticity above one, explaining why its share on consumptions has steadily increased with income growth in the last century.

De Nardi et al. [2010] propose a model that show the role of medical expenditures in asset accumulation of the elderly. This model is structurally estimated using data from the longitudinal dataset *Assets and Health Dynamics of the Oldest Old* (AHEAD). In their model, morbidity risk affects both the mean and variance of medical expenditures, inducing precautionary savings. They consider a model with endogenous health as well, but without endogenous mortality arguing the lack of empirical evidence for such link. Such argument is also used by Khwaja [2010] for not allowing mortality to be determined by medical expenditures. Instead, they assume that individuals get utility directly from medical expenditures under a functional form similar to Equation 9. Nevertheless, some authors still consider the value of considering health investments. This is the case of Ozkan [2014], who considers medical expenditures in two different dimensions of health: curative and preventive. This specialization of investments allows the author to explain why the rich spend more than the poor through life, while the opposite happens at old age. Other works, which rely on calibration of aggregate data rather than estimation of microeconomic data, try to understand the link between medical expenditures and consumption of other goods as Halliday et al. [2015].

Unhealthy behaviours are typically understood under the rational addiction model [Stigler and Becker, 1977, Iannaccone, 1986, Becker and Murphy, 1988]. Preferences exhibit habit formation if it depends on goods that not only affect directly current utility, but also the marginal utility from its consumption in future periods. If current consumption of a good increases the marginal utility of future consumption (adjacent complementarity), there is addiction. An alternative explanation is given by myopic models in which individuals do not fully internalise the impact of their current actions in their future. There is an entire literature devoted to testing rationality, specially for the case of smoking.[12] Here we will focus on Arcidiacono et al. [2007] test that involves a model that is able to accommodate both theories.

Arcidiacono et al. [2007]compare the fit of a life-cycle model with rational addiction but with differing degree of forward-looking behaviour (discount factor). The most extreme scenario is a static model where individuals do not realise the cost on their health of certain choices. Parameters of their structural model are estimated using the *Health and Retirement Study* (HRS), representative for individuals aged 50 and older in the US, where the "exogenous" variation comes from the onset of health shocks rather than tobacco and alcohol prices. In their model, individuals get utility from two lifestyles, alcohol and smoking expenditures, and from consumption of other goods (income is uncertain but exogenous). Both smoking and alcohol intake increase utility, but also both of them increase the odds of transition from good health into bad health or death, and from bad health into death. The addiction component comes from a negative impact on utility of stop smoking or stop drinking. In other words, for the case of smoking, individuals are punished if they are not current smokers but they were smokers the period before. The authors found that a model estimated with an imposed discount factor higher than 0.9 fit better the data than versions estimated with a lower figure. This is interpreted as evidence in favour of the rational addiction theory. Darden [2012] use a similar rational addiction specification but estimates his model with data from the *Framingham Heart Study*, once again finding that individuals adjust their smoking behaviour in response to health innovations. This dataset includes rich objective health information for predicting the onset of cardiovascular diseases. Khwaja [2010] considers both medical expenditures and lifestyle in a model designed for obtaining the WTP for an increase on eligibility to Medicare from age 65 to 67. In this model, on top of lifestyle decisions and consumption, individuals are able to buy medical insurance. This model does not include savings and labour supply, which limits its ability to consider effects of Medicare on assets accumulation.

While the works described above are mostly about the decision to stop an unhealthy habits, there is also work that considers starting decisions. Hai and Heckman [2015] estimate a model on unhealthy behaviour which includes education and wealth using data from the *National Longitudinal Survey of Youth 97* (NLSY97). This model combines health production functions and human capital accumulation, as Attanasio et al. [2015b], but also considers endogenous rational addictions. Health affects choices via several channels in this model.

Another crucial risky behaviour is sexual activity, which could be modeled with similar techniques. For instance, Arcidiacono et al. [2012] and Arcidiacono et al. [2016] consider the case of teen sex. Chan et al. [2015] considers such behaviour in the context of HIV and an medication therapy that reduces both the odds of transmission and mortality rates. In this context, the authors are able to value such

[12] See Chaloupka and Warner [2000] and Cawley and Ruhm [2012] for a survey.

innovation not only from the perspective of those infected with HIV, but also of those who are on risk of infection.

3.3 Subjective beliefs and structural models

One of the main limitations of life-cycle models is their dependence on beliefs and realizations of morbidity and mortality. WTP calculations described in Murphy and Topel [2003a] assume that people know the benefit produced by a given treatment. As an actuarial exercise this is valid, however this might be an issue when we are discussing about the effect of a health treatment on economic choices. For instance, expectations about longevity govern retirement choices, and there is evidence that an unmatch between expectations and realizations might explain very low levels of savings at old age.

This relationship between perceived and actual probabilities have been established in the literature. Viscusi [1990] discuss that in general people underestimate risks that are highly likely but overestimate unlikely events, generating a bias on the willingness-to-pay valuations. A similar pattern have been found in subjective survival probabilities as documented by Hurd [2009], Hurd and McGarry [2002]. There are also interesting puzzles: while subjective expectations about mortality are accurate on average, smokers tend to understate the odds of mortality while never smokers do the opposite [Khwaja et al., 2007].

One of the key contributions to this literature comes from Van der Klaauw and Wolpin [2008], who include subjective expectations data into the estimation procedure of the model. The *Health and Retirement Study* (HRS) and akin studies such as the *English Longitudinal Study of Ageing* (ELSA) elicit several probabilities related to mortality, health and retirement. In this study, data from the odds of being working full-time at age 62 and 65; surviving to age 75 and 85; leaving bequest; and receiving social security benefits were matched with the same objects produced by the model. Essentially, this procedure assumes subjective expectations as important as observed choices. This is an expression of one of the main assumptions behind dynamic models: rational expectations [Rust and Phelan, 1997].

A different treatment of beliefs is considered in the literature as well: learning. Essentially, individuals are allowed to have uncertainty not only about future state variables (health shocks, earnings, unemployment, etc.), but also they might not have certainty about the evolution of these states. Under such consideration, individuals need to observe several realizations of a random variable in order to learn about how the system evolves. Khwaja et al. [2007] document that their finding with respect to smoking and subjective mortality expectations can be explained with Bayesian learning based on partial information. This has serious implications on the *stated preferences* approach for valuing health. Basically, measures derived from this approach do not take into account that individuals do not precisely understand the benefits and/or the costs of a treatment. To the best of my knowledge, there is no literature on how uncertainty affects valuation of medical treatments.

One example of learning is provided by Darden [2012] who proposes a model for smoking behaviour and health information, despite not including elicited subjective expectations. Essentially, individuals learn about the impact of smoking, measured as an index SMK_{it}, on their health via observing objective measures of the risk of developing cardiovascular diseases, an index h_{it}. This index includes measures such as blood pressure, cholesterol levels and a diagnosis of diabetes; all of them variables that can only be observed by a health professional. As shown in Equation 14, this health index is persistent on time and apart from smoking depends on observable characteristics X_{it} and unobserved iid normally distributed innovations v_{it} with variance σ_v^2. As mentioned before, the effect of smoking θ_i is unobserved by individuals, who only know that it is normally distributed and has a population mean $\bar{\theta}$ and variance σ_θ^2. Such population mean is the starting prior, which will be updated every time that the individual observe h_{it}. Learning is Bayesian, so the variance of the belief about θ_i decreases with every visit to the doctor.

$$h_{it} = \rho h_{i,t-1} + X_{it}\phi + \theta_i SMK_{it} + v_{it} \quad , v_{it} \sim N(0, \sigma_v^2) \tag{14}$$

There are models that consider learning which are estimated with elicited subjective information. For instance, Delavande and Kohler [2012] and De Paula et al. [2014] consider learning with respect to HIV status and risky behaviour. Shapira [2013] takes this problem into the life-cycle model. Learning about HIV status becomes relevant not only for risky behaviour but also for fertility choices in his model.

3.4 Valuing adoption of medical innovations

Dynamic labour supply models allow for a better understanding on how individuals incentives are affected due to expected and realised shocks on their health. This knowledge is important for understanding the value of several policy decisions, as discussed in the previous sections. So far I have mentioned some particular applications on social security and, health insurance. However, there are few contributions on how medical innovations affect economic choices, and how is this reflected on the value of a drug.

Papageorge [2014] computes the value of a drug therapy for HIV in the context of a life-cycle model of labour supply with endogenous health and human capital accumulation. The analysed innovation is the introduction of HAART (1996), a drug therapy which drastically reduced the odds of mortality from HIV but at the cost of side-effects. The parameters of the model were estimated using data from the *Multicenter AIDS Cohort Study* (MACS), a longitudinal dataset which includes information for HIV+ men from 1990 to 2003 about detailed perceived and objective health, medical treatment and labour supply choices. As a result, the author is able to produce and identify a model that considers not only the benefits on mortality of the drug, but also the side effects that it has. Such information allows for a model that considers the positive incentives of extended life and better general health on labour supply, but also the negative impact of ailments on the cost of doing so. As a result, the model predicts behaviours such as *optimal treatment cycling*, where individuals take the drug if they are sick, but then leave it once they feel better. Data on health expenditures also allow for a better understanding of the willingness to pay of the drug, as it is based on reveled preferences. Thus, Papagore not only calculates the actual value of HAART, but also of potential counterfactual drug therapies with less notorious side-effects. This framework was expanded for considering risky sex behaviour [Chan et al., 2015].

A less case-specific valuation is studied byRodriguez-Lesmes [2016]. This research considers the case of primary prevention of cardiovascular diseases (CVD) in the UK. For this, he develops a model with labour supply and exogenous health similar to the ones discussed in Section 3.1. Parameters are estimated using data for the *English Longitudinal Study of Ageing* (ELSA), which involved detailed objective measures of the risk of developing CVD. An essential difference with Papageorge [2014] is that given that the setup is the UK instead of the US, there is no private demand of medication but a public system that determines the odds of receiving treatment. Statins, a drug that reduces the odd of CVDs by inhibiting the production of LDL cholesterol, is prescribed by family doctors and do not have serious side-affects. As a result, the author not only stablishes the value of the treatment but also the value of a policy for enhancing the diffusion of the drug therapy in the public system.

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